DOCUMENT RESUME

ED 175 653 SE 028 277

TITLE Bright Idea: Solar Energy Primer.
INSTITUTION Missouri State Dept. of Natural Resources, Jefferson City.
PUB DATE [79]
NOTE 40p.

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Building Improvement; *Electricity; *Energy; Facilities; *Heat; *Heating; *Solar Radiation; Technological Advancement
IDENTIFIERS Energy Education; *Solar Energy

ABSTRACT

This booklet is intended to address questions most frequently asked about solar energy. It provides basic information and a starting point for prospective solar energy users. Information includes discussion of solar space heating, solar water heating, and solar greenhouses. (Author/RE)

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BRIGHT IDEA

SOLAR ENERGY PRIMER

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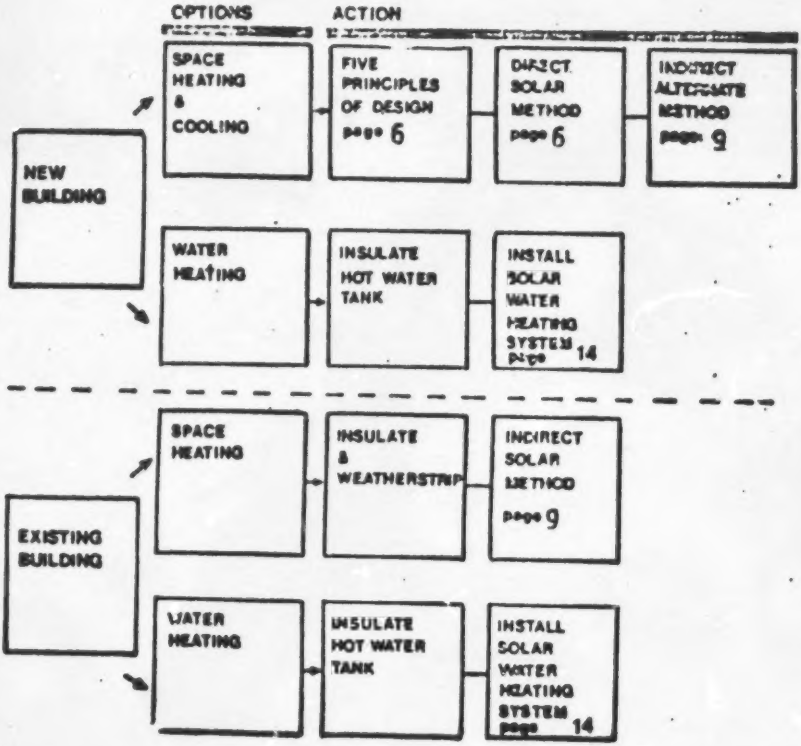
ERRATA FOR PAGES 3 and 5

Solar Options



for an additional solar energy storage and transfer system because the building itself is designed to collect and radiate energy. However, a supplementary heating system is a must. (see page 6)

Indirect (or active) Solar Method — The Indirect Solar Method is a system in which solar heat is collected outside the building and transferred inside the building through ducts or pipes. This method can often be incorporated into a building without altering the traditional design. A supplemental heat source is also needed with this approach. (see page 9)

SOLAR WATER HEATING

Solar water heating is practical for new homes in most areas of Missouri and usually can be added to existing homes. Within approximately 10 years, the building owner may recover the cost of the system through lower utility costs. The cost and length of time required to recover the cost will vary with the specific requirements of each situation and with the rate at which the price of conventional energy sources rises. (see page 14)

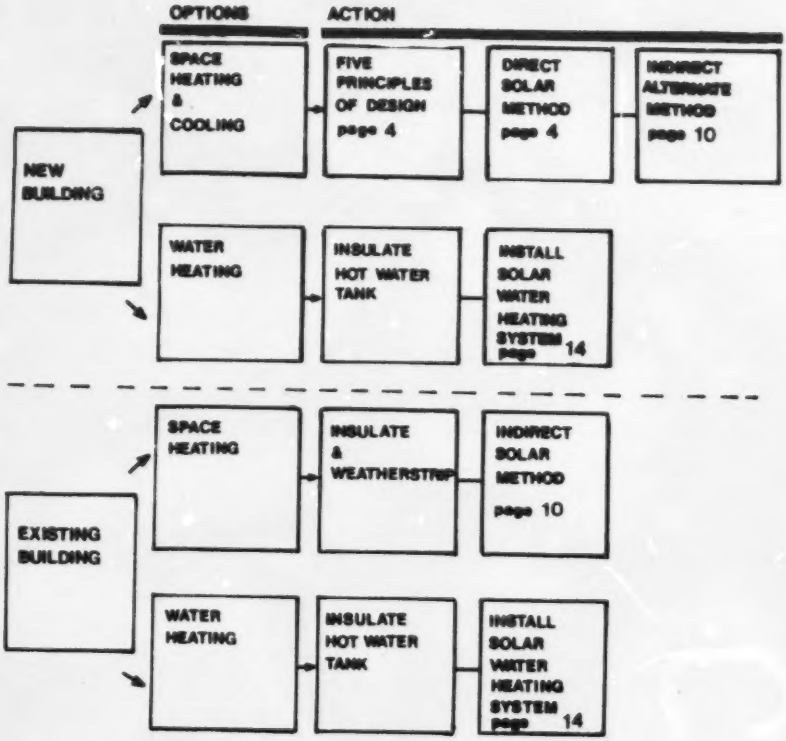
SOLAR GREENHOUSES

All greenhouses use solar energy. A solar greenhouse differs from conventional greenhouses because it retains the sun's energy through the night, thus reducing the demand on supplementary fuel sources. Solar greenhouses can be designed to be either a free-standing structure or to be built next to the home, thus providing an additional source of heat. (see page 14)

PHOTOVOLTAIC (Solar) CELLS

Photovoltaic cells directly convert the sun's energy into electricity. Photovoltaic power conversion involves the direct production of electricity in suitable solid-state devices (solar cells) upon absorption of solar radiation. A solar cell is constructed from elements such as silicon or germanium. Solar cells are not expected to be practical in the near future except for remote and specific applications such as running irrigation pumps.

Solar Options



Overview

Increasing costs of fossil fuel and a greater awareness of the earth's resources have caused Missourians to become more and more aware of the importance of the energy efficient building.

Solar energy has proven to be one way to conserve energy and save money. Using solar systems means less noise, less air pollution, less fire hazard and lower utility costs. Most important, using the sun's energy means saving the earth's finite resources.

However, a building owner who is considering the possible uses of solar energy should first consider conserving the energy he is already using.

The most important step toward energy efficiency, regardless of solar interest, is good insulation. The following are additional steps that can be taken immediately:

*Space heating — Turn the thermostat down to 65 degrees, open drapes on the south or sunny side of the building during the day and turn off heat in unused rooms.

*Space cooling — Turn the thermostat up to 80 degrees, close drapes to block out the sun during the day and open drapes and windows at night. Do not air condition unused rooms.

*Water heating — Turn the water heater thermostat down to 115-120 degrees and use less water.

Using solar principles in a building will require careful thought and a basic knowledge of solar energy. The following is a brief explanation of the uses of the sun's energy:

SPACE HEATING

Direct (passive) Solar Method —

Direct (passive) Solar Method — The Direct Solar Method is usually used when designing and constructing a new building. Using the direct method, buildings are designed to accept or reject sunlight directly, without use of add-on type solar equipment. There is no need

for an additional solar energy storage and transfer system because the building itself is designed to collect and radiate energy. However, a supplementary heating system is a must. (see page 3)

Indirect (or active) Solar Method — The Indirect Solar Method is a system in which solar heat is collected outside the building and transferred inside the building through ducts or pipes. This method can often be incorporated into a building without altering the traditional design. A supplemental heat source is also needed with this approach. (see page 5)

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Solar water heating is practical for new homes in most areas of Missouri and usually can be added to existing homes. Within approximately 10 years, the building owner may recover the cost of the system through lower utility costs. The cost and length of time required to recover the cost will vary with the specific requirements of each situation and with the rate at which the price of conventional energy sources rises. (see page 10)

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SOLAR AIR CONDITIONING

Indirect (active) solar air conditioning is currently not cost effective for single family residences or small commercial buildings. It may achieve cost effectiveness for large (primarily commercial) application.

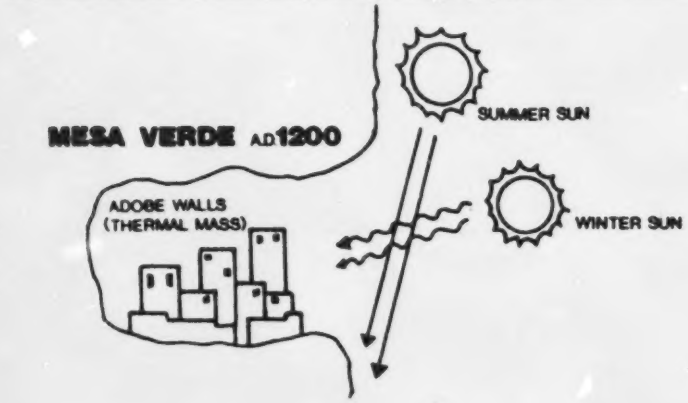
The simplest way to cool a home is through natural means. This is addressed in the Missouri Department of Natural Resources publication, Bright Idea #8 Cooling.

Space Heating

I. Direct Solar Method: A Lesson From the Past

Direct (passive) solar buildings are designed so they accept or reject heat directly without the use of solar hardware. A properly designed and constructed passive building may provide heating and cooling at a lower cost than alternative systems.

Many ancient civilizations designed their buildings using direct solar design. The cliff dwellers of Mesa Verde in New Mexico constructed their buildings using the principles of direct solar heating and cooling as early as 1200 A.D. Today, these buildings still heat and cool naturally. During the winter, the warming rays of the low winter sun can enter and heat the structures. During the summer the interior of these buildings is kept relatively cool because the rays from the high summer sun cannot enter.



Beginning with the following five basic solar design principles, modern buildings can take advantage of the local climate in their area to let natural forces keep the building comfortable.

1. Insulate and weatherstrip the building thoroughly.

TYPE OF INSULATION

	BATTS OR BLANKETS		LOOSE FILL (POURED-IN)			FOAM	
	glass fiber	rock wool	glass fiber	rock wool	cellulosic fiber	expanded polyurethane	expanded polystyrene
R-19	6"-6½"	5¼"	8"-9"	6"-7"	5"	3"-4"	4"-5"
R-30	9½"-10½"*	9"*	13"-14"	10"-11"	8"	5"	7"

The Department of Natural Resources recommends the following for new homes: Wall insulation with a heat flow resistance factor of at least 19 (R-19); ceiling insulation with a heat flow resistance factor of at least 30 (R-30); double glazed windows: exterior styrofoam on basement walls; and insulated doors.

2. Design the building so that the longest exterior wall faces south.

3. Place most of the windows on the south side of the building and provide shading. Avoid windows on the north side.

4. Cover the roof with a light color surface material.

5. Build an appropriate overhang on the south side to block out the high summer sun yet permit entrance of winter sun.

   An equation used to estimate the optimum length of the overhang is:

$$\text{Overhang} + \frac{(\text{Latitude in degrees}) \times (\text{window height in inches})^*}{50}$$

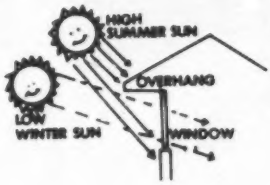
*The height of the window is equal to the distance between the bottom of the overhang and the bottom of the window.

For your specific latitude, look on any road map; e.g., St. Louis and Kansas City 39 degrees and Springfield 37 degrees.

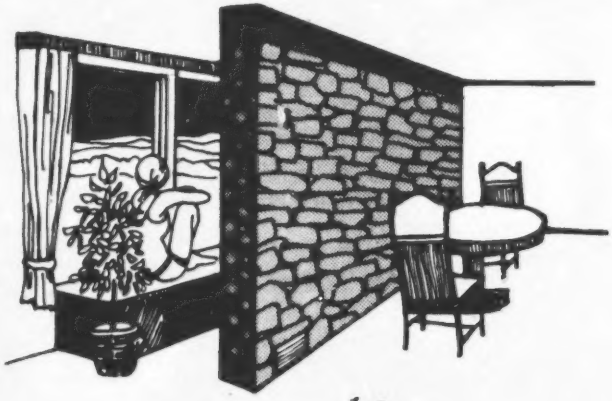
An example of the formula for a 35" window is:

$$\text{For St. Louis: } \frac{(39°) \times (35")}{50} = 27.3"$$

The overhang should extend approximately 27 inches beyond the wall to effectively block out the summer sun.

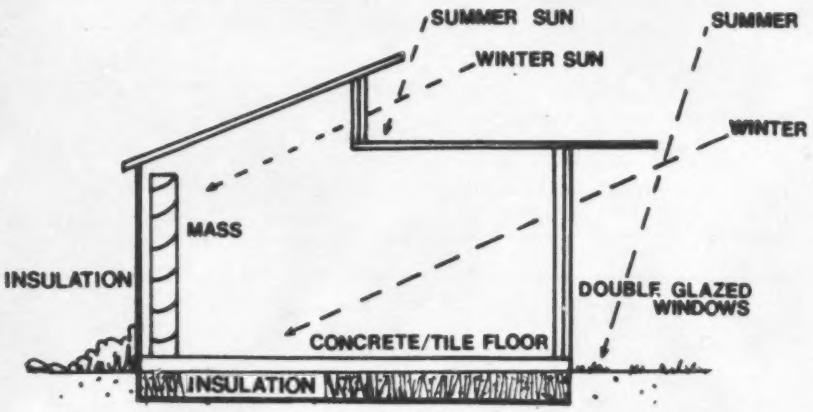


Another measure to increase the heating and cooling potential of the building is to provide more thermal mass. Dense materials such as concrete, masonry, adobe, and rocks will serve this purpose. These materials are used for walls and floors because of their capacity to store heat. It is important to note that thermal mass is not enough in itself. All mass must be insulated, preferably from the outside. For heating thermal mass located inside the building, the south window area should be designed to allow the sun's rays to enter the structure and directly heat the mass.



Some solar homes use a "Trombe wall" as thermal mass. Painted a dark color and placed directly in line with a south-facing window, the wall absorbs the sun's heat during the day and releases it slowly at night.

If the floor is used as the mass/storage, it should not be glossy. It should be a dark or subdued color with a textured finish. This will allow the heat to be more completely absorbed.



In the summer, the building is kept cool by blocking the direct rays of the sun with the use of an appropriately designed overhang, moveable insulation or trees which shed their leaves in the winter. Since the mass is kept out of the direct sun in the summer, it remains cool and helps cool the entire structure.

II. Indirect (active) Solar: An Alternative Method of Space Heating

Another way to heat space is with the indirect active approach. This method collects the solar heat outside the building and transfers it inside through ducts and pipes.

Indirect systems can be applied to new buildings or added to existing buildings. There are two main parts used in the indirect (active) solar method — a collector device and a storage system. There are two effective mediums which can be used to collect and transfer solar heat — air and water.

The collector is made of the following parts:

*A glass or plastic cover to admit the sun's rays and to prevent the collected solar heat from escaping.

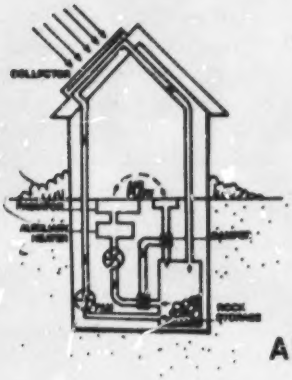
*A metal sheet painted flat black or another dark, absorbing color with tubes, corrugations or fins to convey the solar heat to water or air.

*A layer of insulation behind the metal plate to prevent heat loss through the back of the enclosure.

*A weatherproof enclosure to hold and protect the parts mentioned above. The collector is fastened on the south exterior wall or on the roof.

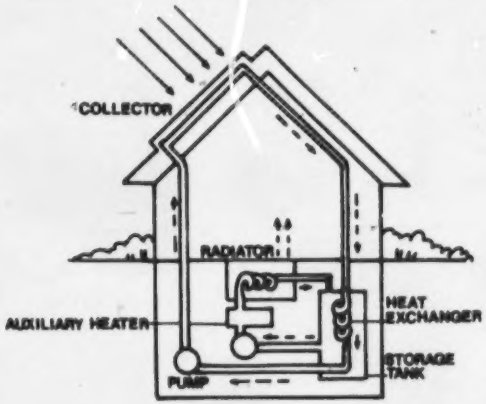
The collector and storage systems used are:

AIR COLLECTOR/ROCK STORAGE — This system circulates air through the solar collectors, carrying the heated air to storage or directly to the building for immediate use. These systems most often use a flat-plate collector located on the wall or roof and a bin of one to three inch rocks for storage. Hot air flows through the spaces between the rocks and heats them. Air from the cold end of the rock storage bin is blown up to the lower end of the collector, heated, drawn off the hot upper end, and returned to the bin. When the living space of the house needs heating, dampers in the air ducts are adjusted and hot air is blown from the storage bin into the living space. Heating coils from an auxiliary heating unit also are provided.



AIR

LIQUID COLLECTOR/LIQUID STORAGE — In this type system, a heat transfer fluid (usually water with an antifreeze mixture and anticorrosion additive) is pumped through the collector where it is heated. It then is pumped to the storage tank and passes through a heat exchanger coil, where the heat from the fluid is transferred to the liquid in the storage tank. The newly heated fluid in the storage tank is pumped to the radiator in the living room. The remaining water in the storage tank is pumped through the collector where it is again heated and the cycle starts over.



LIQUID

Both systems should be investigated to arrive at the most effective solution. Water currently is the most popular medium. When adding to an existing system, the heating and cooling method already in use will determine the best medium. A forced air circulation system is most compatible with an air collector system, but also can be used with liquid systems. Hot water radiant systems, such as baseboard radiators, work well with liquid systems. The system already in use will provide a backup for the solar heating system.

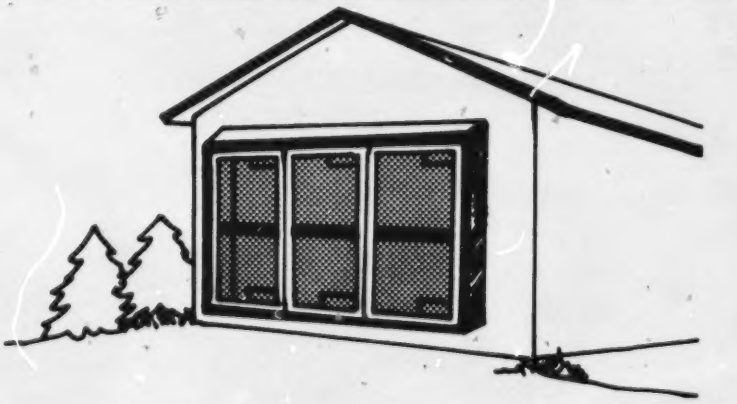
There are advantages and disadvantages to both the air and liquid systems. The advantages of air systems are that they use relatively simple hardware and there is no potential for leaks, freezing, or corrosion. The disadvantages are the large ducts and storage systems. Liquid systems require less than half the storage volume of an equivalent air system and smaller pipes for heat transfer. However, water systems require more complex plumbing and hardware.

SOLAR ADDITIONS

Solar wall collectors, solar greenhouses, and solar water heaters are three possible ways to incorporate the sun's energy in buildings already being heated by conventional energy sources. The Missouri Department of Natural Resources has blueprints available, free of charge, to persons interested in these three solar additions. Send requests to the Missouri Department of Natural Resources, Energy Information Clearinghouse, Box 1309, Jefferson City, MO 65102.

I. Wall Collector

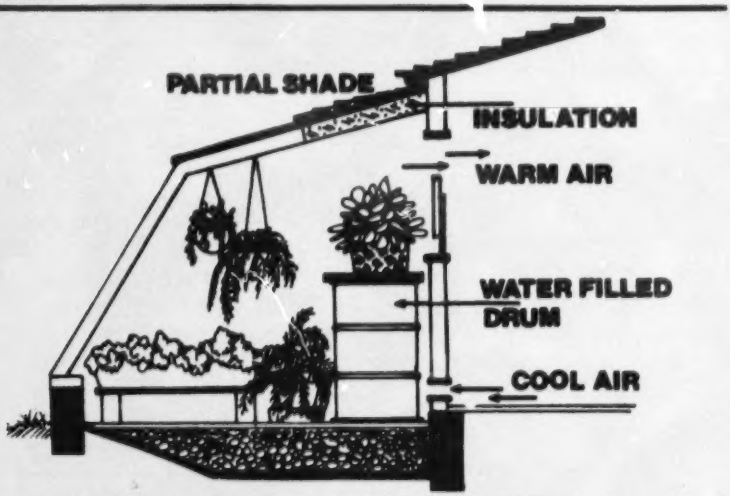
If there are only a few windows on the south side of your house, you can put a solar collector on the outside wall. The wall collector is a box-like construction added to a portion of the south wall and covered with either glass or fiberglass. Holes have been cut in the wall to allow cool air from the building to enter the collector from the bottom. The air, warmed by exposure to the sun, rises to the top of the collector and is drawn back into the room through holes cut in the top of the wall. Within the collector there usually are a series of baffles to slow the air movement through the collector extending the length of time the air is exposed to the sun's rays. A wall collector can be built to utilize the thermosiphon principle (see glossary) or can be fitted with a blower.



A wall collector probably will not heat an entire house; however, it is possible for the collector to heat a portion of the house for several hours during the day when there is direct sunlight. A thermosiphon collector is pictured below.

II. Solar Greenhouse

A solar greenhouse essentially is designed to capture and retain energy more efficiently than conventional greenhouses. The heat is transferred through ducts or window areas to the adjacent living spaces.



*For more detailed information consult:

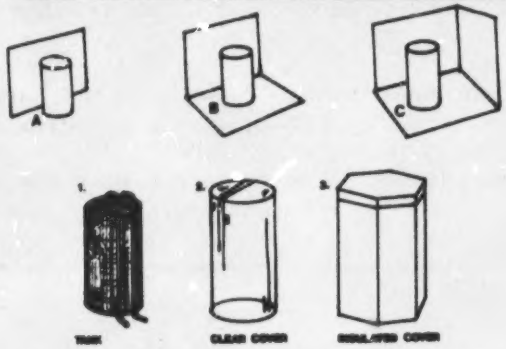
Eccli, Eugene and Sandy. **Save Energy, Save Money.** Washington: Institute on Energy Conservation and the Poor; Office of Economic Opportunity, 1974. (Available from the National Center for Community Action, 1711 Connecticut Avenue, NW, Washington, D.C. 20009).

III. Solar Water Heating Systems

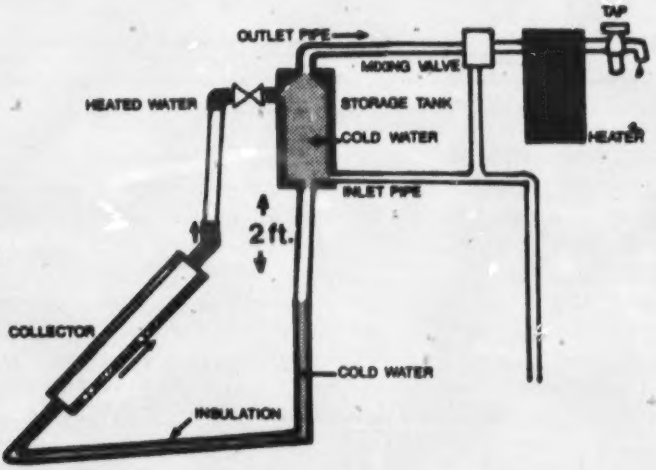
In many cases, solar heating is a cost-effective and practical application for water heating. The following are four possible approaches to solar water heating.

Direct Gain Solar Water Heating — Perhaps the simplest and most cost-effective approach for solar heating is to have the storage tank collect energy. There are several designs which accomplish this, but the most popular designs are variations of the "breadbox" or the "Pro" style water heater. Each design is shown below. The basic concept of both designs is to allow the sun's rays to strike the glass-lined or galvanized tank during the day while providing a means for

insulation to minimize heat loss. Frequently a reflector is used to increase the amount of energy striking the collector. Solar water heaters generally will not provide all of the energy required for the domestic hot water supply and for that reason should be thought of as preheaters.

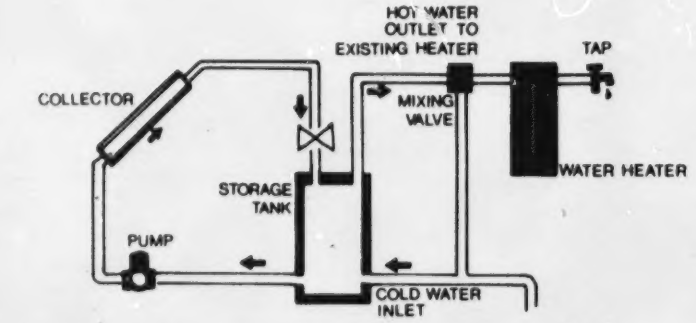


Thermosiphon — A simple solar water heating system is called a thermosiphon. It operates on the principle that cold water in a water tank will sink and so cause hot water to rise. The water heated in the solar collector will flow up into the storage tank.



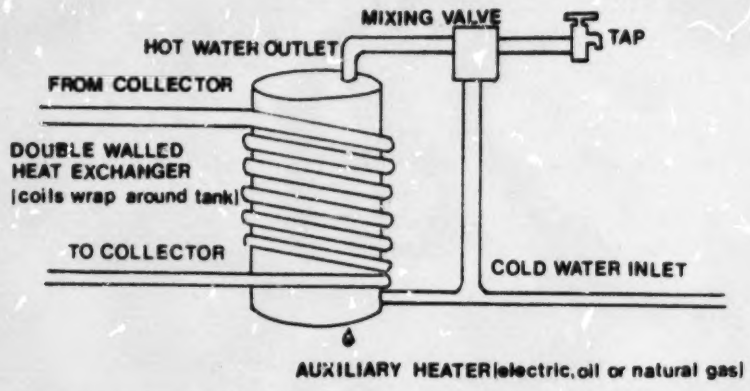
The bottom of the storage tank must be at least two feet above the top of the collector to prevent water from circulating in the wrong direction. In many cases the difficulty of installing the tank above the collector makes the system too expensive. The thermosiphon system eliminates the need for pumps and controls. In Missouri where freezing is a factor, a closed system with a heat exchanger is necessary.

Pumped Solar Water Heating — If the storage tank cannot be placed above the collector, a small pump may be used to circulate the water. Combined with a temperature control system, the pump will move the water through the collector only when the water in the collector is warmer than the water in the tank.



Pumped Water Heating with a Heat Exchanger System — In locations where freezing is common, a dual system with a heat exchanger is recommended. The heat exchanger system requires only a single tank with an auxiliary heater. A fluid containing an anticorrosion additive and an antifreeze additive is circulated through the collector and into the storage tank. Because this fluid is extremely toxic it must not come in contact with the potable water supply. This mixture is also very expensive when compared to untreated water; therefore, it is often desirable to limit the use of the fluid. To counteract these problems a heat exchanger is required. With the

heat exchanger, the heat of the circulating fluid is transferred to the water supply which serves the house. One possible heat exchanger is pictured below.



These ideas are relatively inexpensive ways to incorporate solar energy into a building; however, the following questions should be considered to determine if the addition is to be cost-effective for you.

If there are any questions you cannot answer, do some of your own research: check with contractors, solar dealers and manufacturers. The Missouri Energy Program at the Missouri Department of Natural Resources, P. O. Box 1309, Jefferson City, Missouri 65102, (314) 751-4000, also may be able to aid you.

Collectors

1. Does the collector site get full sun? It is important that the collectors face as close to due south as possible. However, they can operate if they are as much as 45 degrees off due south.

2. Is there sufficient area to accommodate the solar collectors?

3. Will the system operate without interfering with the operation, replacement, maintenance, etc. of existing equipment?

4. Will the roof support the additional weight of solar collectors? (In most cases, placing collectors on the roof will not require structural modifications for their support)

5. Will it be convenient to mount and tie down the collector supports if they are needed?

6. Will it be convenient to waterproof the new roof jacks, structural penetrations, etc.?

7. Will the system be protected from potential vandalism?

Storage Tank

1. Is there adequate space for an additional storage tank?

2. Can the storage tank be located close to the backup water heating system and also close to the collectors?

Pipes, Pumps and Miscellaneous

1. Can new piping be conveniently routed to the probable collector location?

2. Can new plumbing be connected to the solar system and backup system?

3. Is there an appropriate location for new pumps and controls? (A thermosiphon won't need pumps)

4. Is there access to an electricity source to run the pumps and controls?

5. Will all pipes and storage be well insulated for maximum efficiency?

INVESTMENT

I. Consider all factors

The initial cost of a solar heating system is higher than a conventional system. Because of the higher cost, load requirements must be figured more closely when planning the solar installation. To keep equipment costs at a minimum and to insure efficient solar system operation, improved insulation and conservation features are necessary for new construction as well as for older homes. In addition, the conventional system which must be installed as a backup will add to the total cost.

However, in the long run, the cost of solar heating systems may be lower than other systems. Both lifetime and initial costs are important considerations when buying a solar system. Passive systems (usually for new homes) are generally less expensive than active systems installed in either old or new homes. Factors determining the cost of a solar system include the initial equipment costs, the amount of down payment, mortgage interest rates, mortgage payback period, income taxes, local fuel costs and climate variables.

To determine the feasibility of a solar system, compare the money spent on the system (investment) with the savings gained from the system (return).

investment cost/debt	return/credit
1. initial costs	1. annual fuel savings
2. anticipated annual maintenance	2. possible appreciation on home
3. interest and principal payments on loan	3. possible federal and state tax incentives
4. extra insurance	4. tax deduction on interest payments
5. possible tax increases	5. inflation of conventional fuel prices

Compare the results of these calculations and determine the amount of time needed to recover the investment. If the payback period is 10 years or less, and the system is substantial enough to endure that time length, the investment may be beneficial. If the payback is 20 years or longer, the risk will be appreciably higher.

In addition, it is necessary to calculate the expected performance of the solar system. For all solar systems — hot water and space — the following data is needed for a thorough calculation of the BTU return: monthly solar insolation data; monthly average temperature; monthly average wind velocities; daily degree data and percentage of sunny days.

In addition to the weather data, a proper evaluation of anticipated benefits requires more information based on the objective of the solar system. The following data are needed to determine the design specifications for the system.

Hot Water Systems — Type and capacity of existing water heater; number of hot water outlets; list of appliances using hot water; number of persons in the household, fuel consumption of existing water heater, desired water temperature, time of day when most hot water is used; and temperature of cold water supply.

Space Heating — House orientation, floor area of the house, number of stories, type of construction, type and extent of insulation, house heat loss including infiltration and ventilation, previous bills and rates, and desired temperature levels.

In addition to the weather and specific use data, topographical information, latitutde, aititude, and characteristics of the specific site — hills, trees, valleys also will be considerations.

II. How to Buy

When buying solar equipment consider these things:

* Experienced company.

Some of the well-known names in solar heating and cooling will back up claims against their dealers. However, the big companies may be more expensive.

* Method of contact.

Did they solicit you or did you find them? A referral from a satisfied customer is the best way to choose a company. If you do not have a referral, ask the company you're considering dealing with for the names of people they have serviced. Contact the people. If they are satisfied, chances are you will be too.

* Exaggerated claims

There is very little difference in the performance of solar collectors. The difference in cost is in the quality of construction. (Check for rainproofing, guarantees, etc.) The salesman may claim that the collector is 70 per cent efficient, but you should be aware that by the time the collector is set up and joined to pumps and tanks the overall efficiency is down to 30 to 35 per cent, which is considered acceptable. Further, efficiency varies considerably because it is dependent on inlet and ambient temperatures.

Be cautious of the sales person who claims that the system will take care of 100 per cent of your space heating needs. Very few companies design for more than 80 per cent of heating needs.

* Inferior material and workmanship

Before you invest be sure to examine the collector yourself. Check the rain-tightness of all exposed parts. The tubing should be copper; the flat plate can be iron, aluminum or copper. Check how well the copper tubing is attached to the plate. Check insulation. Foam plastic is the best insulation, but glass wool is acceptable if it is about three inches thick. Are the joints in the box square? If plywood, is the finish weather proof for the long term? Is the plywood of an exterior quality?

* Hidden extra costs

The cost of the collector is only about 50 per cent of the total system cost, so don't dismiss labor, pumps, pipes, storage tank, automatic controls, etc.

Solar plumbing is different from regular plumbing. Make certain your plumber has installed solar systems before.

Obviously, no set of rules is going to protect you from every error. Ask for details and use common sense and you won't be flim-flammed. You'll soon be heating with solar energy.

III. Government Grants

If you live in or plan to build a residential building, financing for solar systems may be available through the Department of Housing and Urban Development (HUD). For information on the Residential Non-Federal Building Demonstration Program write:

National Solar Heating and Cooling Information Center
P. O. Box 1607
Rockville, MD 20805

If you have a solar energy proposal not covered by an existing program, the unsolicited proposal may be financed if it is unique and innovative. Guidelines for the preparation of unsolicited proposals can be obtained from:

ERDA Technical Information Center
P. O. Box 62
Oak Ridge, TN 37830

Federal law requires that the National Bureau of Standards evaluate all promising energy related inventions, particularly those submitted by individual inventors and small companies. If you have a good idea for an invention, you are encouraged to contact:

Office of Energy-Related Inventions
National Bureau of Standards
Washington, D.C. 20234

IV. Where to Go For More Information

*Federal Agencies

National Solar Heating and Cooling Information Center
P. O. Box 1607
Rockville, MD 20850
*800-523-2929 toll free

Energy Research and Development Administration
Technical Information Center
P. O. Box 62
Oakridge, TN 37830
615-483-8611 ext. 4161

National Energy Information Center (NEIC)
Federal Building FEA
1200 Pennsylvania N.W.
Washington, D.C. 20461
202-566-9820

U. S. Department of Commerce
National Technical Information Service
Springfield, VA 22161
703-321-8543

*Associations and Societies

Alternative Energy Co-Operative (Berkeley)
2231 Woolsey St., Berkeley, CA 94705
or, P. O. Box 66959
Scotts Valley, CA 95066

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHEAE)
Research and Technical Services 345 East 47th Street
New York, NY 10017

International Solar Energy Society (ISES)
c/o Florida Solar Energy Center
300 State Road 401
Cape Canaveral, FL 32920

National Assoc. of Home Builders (NAHB)
NAHB Research Foundation, Inc.
P. O. Box 1627
Rockville, MD 20850

Northern California Solar Energy Assoc.
P. O. Box 1056
Mountain View, CA 94042

Southern California Solar Energy Assoc.
City Admin. Building 11-B
202 - C Street
San Diego, CA 92101

Solar Energy Advocates
P. O. Box 876
Sacramento, CA 95814

Solar Energy Industries Association
101 Connecticut Ave., NW
Washington, DC 20036

Solar Energy Institute of America
P. O. Box 6068
Washington, DC 20005

Solar Energy Society of America
P. O. Box 4264
Torrance, CA 90515

Solar Utilization Now of Resources and Employment (SUNRAE)
P. O. Box 915
Goleta, CA 93017

*Missouri Associations and Societies

In the state of Missouri there is a particularly active group of solar energy advocates, the Missouri Solar Energy Associates. The goal of the group is the promotion of energy self-reliance through energy-efficient construction, solar home heating and solar water heating. There are various chapters located throughout the state. Membership is not restricted. For information contact the agencies listed below. Please enclose a self-addressed stamped envelope to facilitate a reply.

Missouri Solar Energy Associates (MSEA)
Columbia
Gorden L. Moore
2008 Engineering
University of Missouri
Columbia, Mo. 65201

MSEA Kansas City
P. O. Box 17757
Kansas City, Mo. 64134

MSEA St. Louis
10961 Olive
St. Louis, Mo.

Missouri Solar Energy Associates
c/o W. H. Knight, Chairman
R.F.D. #5
Warrensburg, MO 64093

Southwest Missouri Solar Energy Association
4911 Glenstone Station
Springfield, Missouri 65802

Bibliography

I. In Perspective

Rays of Hope, The Transition to a Post-Petroleum World, Denis Hayes, W. W. Norton and Company, 500 Fifth Ave., N.Y. 10036, 1977, $3.95, 240 pp.

II. Solar Energy for the Home

Bennett Sun Angle Chart, (Refer to any map for your latitude). Robert Thomas Bennett, 6 Snowden Road, Bala Cynsyd, Pa. 19004. These charts may be purchased for latitude 24 degrees through latitude 52 degrees in 2 degree increments. The cost is $2 plus a 50 cent postage charge for each chart ordered.

Energy Primer - Solar, Water, Wind and Biofuels, Portola Institute, 1974. This book can be ordered from the Whole Earth Truckstore, 558 Santa Cruz Ave., Menlo Park, CA 94025. $5.50, 200 pp.

Fuel Savers - Dan Scully, et al., Cheshire Books, Church Hill, Harrisville, New Hampshire 03450. Do-it-yourself low cost solar retrofits. $3.00, 60 pp.

Low-Cost, Energy-Efficient Shelter for the Owner and Builder, edited by Eugene Eccli, Rodale Press, Inc., Emmaus, PA 18049, 1976, $5.95, 408 pp.

Nicholson Solar Energy Catalog and Building Manual, Dick Nicholson and Bruce Davidson, Renewable Energy Publications, Ltd., P. O. Box 216, Frenchtown, N.J. 08825, 1977, $10.00, 150 pp.

Other Homes and Garbage — Designs for Self-Sufficient Living, Jim Leckie et al., Sierra Club Books, San Francisco, 1975, $9.95, 302 pp.

Solar Dwelling Design Concepts, U. S. Department of Housing and Urban Development, Superintendent of Documents, U.S. Government Printing Office - Washington, DC 20402, Stock number 023-000-00334-1, 1977, $2.30.

Solar Heated Buildings - A Brief Survey, 10th Edition, W. A. Shurcliff, Cambridge, Mass., 1975, From Solar Energy Digest, P. O. Box 1776, San Diego, CA 92117.

Solar Home Book, B. Anderson and M. Riordan, Cheshire Books, Church Hill, Harrisville, NH 03450, $7.50, 297 pp.

The Owner Built Home, Ken Kern, Charles Scribners Sons, New York, NY, 1972. Written by a California architect and builder, this book places emphasis on inexpensive and/or earth-related materials and good, sound design and construction techniques. $6.95, 373 pp.

III. Advanced Materials

Applied Solar Energy - An Introduction, Aden B. Meinel and Marjorie P. Meinel, Addison - Wesley Publishing Co., 1977, $17.50, 350 pp. hardbound.

Solar Energy: Fundamentals in Building Design, Bruce Anderson, McGraw-Hill, 1977, $17.50, 350 pp. hardbound.

Solar Heating and Cooling, Engineering, Practical Deisgn and Economics, Jan F. Kreider and Frank Kreith, McGraw-Hill, 1977, $24.75, 342 pp. hardbound.

GLOSSARY

The following glossary was adapted from "Sun Language", a study of solar energy terminology b[illegible]. O. Smith Corporation.

ABSORBER PLATE The part of the collector which ultimately takes solar energy into the system is designated an absorber or base plate. The plate transfers the heat to a working fluid whose internal energy is thereby increased. Also see COATING, COLLECTOR AND WORKING FLUID.

ABSORPTIVITY Absorptivity is the measure of the absorber plate's ability to absorb longwave (infrared) radiation from the sun. It is expressed as the ratio of incident radiant energy absorbed by a surface to the total radiant energy falling on the surface. This characteristic is improved by coating the absorber plate with a preparation which increases inward heat gains. Also see COATING and REFLECTIVITY RE-RADIATION.

ACTIVE SYSTEM A solar energy system which uses energy sources other than solar to make collected solar energy available for storage or for use. Also see PASSIVE SYSTEM.

AMBIENT This term is usually applied to the air temperature surrounding a part of the system such as the collector. The monthly average ambient air temperature is normally used to establish the temperature difference between the collector inlet and the air. The smaller the temperature difference between these two values, the more efficiently the collector will operate.

ANGLE The angle at which the collectors are tilted to the sun depends upon both the application and the latitude. For example, the collectors on a system located at 42° N latitude should be tilted to 57° from horizontal. A water or pool heating system is best tilted to an inclination equal to the local latitude or -15° for summer pool heating. In latitudes where frequent snows are encountered, collectors may be inclined to 50° or more to reduce accumulations. In effect, tilting the collector surface from horizontal to be more nearly at right angles to the sun's rays is the optimum angle. Also see ORIENTATION.

ARRAY A group of collectors placed so that they best collect the sun's rays. Also see ORIENTATION.

ASHRAE 93-77 Standard for testing and rating solar collectors.

ASHRAE 94-77 Standard for testing and rating of solar devices and thermal storage devices.

BACKUP HEAT A constantly available source of heat energy which is brought into operation when the solar system storage has been exhausted and the need for heat exists.

BTU The abbreviation for the British thermal unit is Btu. One Btu is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit. When liquid fluids other than water are used in solar systems or are mixed with water, the quantity of heat required to raise a quantity of the solution a given amount will be less. In other words, more solution would have to be moved to do the same amount of work as water. Also see SPECIFIC HEAT.

BUILDING ENVELOPE The outer structure of the building.

CATHODIC PROTECTION The process of providing corrosion protection against electrolytic reactions which could be detrimental to the performance of the protected material or component.

CLOSED LOOP SYSTEM A system in which the liquid solar heat transfer fluid is freeze inhibited to allow operation in below freezing climates. The fluid in turn heats the potable water through a heat exchanger. Also see OPEN LOOP SYSTEM and POTABLE WATER.

COATING The dark or blackened finish which is applied to the side of the collector plate exposed to the sun's rays is called a coating. Often called a (wave-length or optically) selective coating, its purpose is to maximize absorption of the sun's energy. The absorptivity and emissivity characteristics of the coating affect collector performance. While ordinary black paint absorbs solar radiation it also re-radiates heat at a significant rate. Therefore "selective" coatings have been developed which have high solar radiation absorbance and low emissivity or infrared emittance. Silicon polyester, electroplated black chromium or nickel and vapor deposited tungsten are examples of selective coating materials.

COLLECTOR A device for intercepting the sun's rays and directly converting them to a conveniently transportable form of energy, such as heat or electricity.

COLLECTOR EFFICIENCY The ratio of the energy collected to the incident radiation on the collector is used to measure collector efficiency. Also see INCIDENT RADIATION.

CONCENTRATING COLLECTOR A focusing or concentrating collector is a solar collector that contains reflectors or refractors which concentrate the solar energy falling on the aperture onto an absorber plate of smaller surface area than the aperture. This type collector achieves high temperatures but can utilize only direct solar radiation.

CONDUCTION The transmission of heat by the passage of energy from particle to particle is called conduction. To reduce energy losses insulation is placed behind and around the collector frame or box.

CONVECTION Heat travel by the movement of fluid currents is called convection. It is partly for this reason that transparent cover plates are placed over the absorber plate . . . to reduce the loss of heat by convection to moving air currents. Also see CONDUCTION and RADIATION.

COST EFFECTIVE When savings in energy exceed total cost of system or innovation employed. Also see LIFE-CYCLE-COSTING and PAYBACK.

COVER PLATE The glass or optically suitable plastic which is placed over the absorber plate is known as a cover plate. The cover plate is used to create layers of stagnant air, minimizing heat losses to the air from the collector surface, and to reduce re-radiation of the sun's rays in the infrared spectrum. Each glass cover plate reduces the incoming solar radiation by up to 8% because of the reflection at the two cover-air interfaces.

The effect of dirt and dust on cover plates is small and the normal washing of rain is usually adequate to maintain transmittance within 1% to 4% of normal.

DEGREE DAY (DD) The degree day is a unit of climate measurement equal to one degree variation from 65° standard temperature in the average temperature of a single day.

DELTA T (ΔT) As used in solar work the term designates the difference in temperature between outside ambient air and either inlet or outlet temperature of the fluid passing through the solar collector. As a rule, the higher the Delta T the lower the collector efficiency. When comparing the performance of two collectors at a given Delta T the one with the higher efficiency is the better performer. The term Delta T is commonly used to designate temperature differences between any two temperature readings.

DENSITY The ratio of the mass of an object to its volume. Under given conditions at sea level, the density of air is 0.075 lbs./ft.^{3}. The density of water is 62.4 lbs./ft.^{3}. These facts demonstrate that if air is used as the heat transfer fluid in a solar energy system much more of it, compared to water, must be transported to handle a given load. Also see SPECIFIC HEAT.

DIELECTRIC FITTING An insulating or nonconducting fitting used to isolate electrochemically dissimilar materials. Also see CHEMICAL COMPATIBILITY.

DIFFERENTIAL CONTROL OR THERMOSTAT A device to start fluid circulation when the temperature in the collector is greater than that in the storage. Circulation will stop when collector temperature drops or storage temperature is satisfied. The control may operate the circulator in an on-off fashion or (proportional differential type) at a variable speed.

DIFFUSE (COMPONENT OF RADIATION) This is one of the two components of solar energy arriving at the earth's plane. The quantitative relationship between these two components, diffuse and direct, varies considerably throughout the world. Diffusion is caused by clouds, airborne contaminants and moisture. The amount of diffusion will vary during the day as the causes of diffusion change. For example, high humidity in the early morning will generally decrease later in the day. As much as 10% of solar radiation may be received as scattered or diffuse radiation even when the sun's rays are apparently obstructed. Diffuse radiation prevails on cloudy days. Also see INCIDENT RADIATION.

DIRECT (COMPONENT OF RADIATION) This is one of the two components of solar energy arriving at the earth's plane. The quantitative relationship between these two components, direct and diffuse, varies considerably throughout the world. This is the direct beams of the sun's rays which reach the collector by passing through the atmosphere in a straight line. Also see INCIDENT RADIATION.

EFFICIENCY The ratio of the amount of heat usefully collected to the solar energy available to the collection surface.

EMISSIVITY Emissivity is the measure of the absorber plates ability to emit or re-radiate longwave (infrared) radiation back to the atmosphere. This characteristic is reduced by coating the absorber plate with a preparation which minimized outward losses. Also see COATING and RE-RADIATION.

FLAT PLATE COLLECTOR A flat plate collector is one which is capable of collecting both direct and diffuse components of solar radiation. This is an obvious advantage of flat plate collectors over focusing collectors which collect only direct radiation.

FOSSIL FUEL This term refers to natural gas, oil or coal and in some cases is used to refer to electricity generated by those fuels.

GETTER (COLUMN) The getter column is a serviceable filter used to minimize galvanic corrosion between two dissimilar metals in systems using liquid solar heat transfer fluid. In a system using an aluminum absorber plate and copper piping the getter column, consisting of pieces of aluminum and filter material, would be placed in the collector supply line, immediately before the collector. Any cathodic copper particles in suspension will be deposited on the aluminum.

GLAUBER'S SALT An inexpensive material used for storing heat gathered by solar systems. In melting within a 2°F spread at about 90°F the salt absorbs a great quantity of heat, approximately 108 Btu's per pound. The stored heat can be extracted later for night-time heating or other uses. Also see LATENT HEAT.

GLAZING See COVER PLATES.

HEAD PRESSURE This term designates the capacity of a liquid circulator and is another way of expressing pressure drop. The maximum "head" of a pump is actually the maximum pressure drop against which the pump can induce a flow of liquid. The rating of a circulator is usually expressed in feet of water. Also see PRESSURE DROP.

HEAT EXCHANGER A device for transferring thermal energy from one fluid to another. Also see CLOSED SYSTEM.

HEAT LOSSES This term is used to describe loss of heat which the collector has absorbed from the sun's rays. The losses occur through conduction, convection and radiation. Also see CONDUCTION, CONVECTION, INSULATIONand RADIATION.

HELIOSTAT A mirror which reflects the sun's rays into a collector.

INCIDENT ANGLE The angle between direct sun's rays and the surface it is striking. The importance of this angle is that it determines both the intensity of the direct radiation component striking the surface and the ability of the surface to reflect, transmit, or absorb the sun's rays.

INCIDENT RADIATION Energy arriving at the surface of the collector is defined as the total incident radiation ($^{I}T_{t}$). It includes both direct and diffuse components of the solar radiation.

INFRARED The invisible rays just beyond the red of the visible spectrum are called infrared. Their wave-lengths are longer than those of the spectrum colors (.7 to 400 microns) and they have a penetrating heating effect. Infrared radiation is also one of the ways in which the solar collector loses heat to the atmosphere by re-radiation of the sun's rays from the cover and absorber plates. Part of the cover plates function is to reduce this loss. This is because heat radiated by objects less than 1000°F temperature is almost entirely by infrared radiation.

INSOLATION Solar insolation is the radiant energy from the sun received by a surface such as the collector.

INSULATION A material used to reduce the passage or leakage of heat. The back and sides of a collector are usually insulated to prevent the loss of absorbed heat by conduction to the air and colder parts of the supporting structure.

IRON-FREE (GLASS) Minimizes internal absorption of heat into the glass which reduces the amount received by the absorber plate. Edges of glass which appear green have a relatively high iron content.

IRRADIATION See ISOLATION.

KILOWATT A unit of electric power equal to one thousand watts. One kilowatt produces 3,413 Btu and is equal to about 1-1/3 horsepower.

LANGLEY A unit of measurement of solar radiation. One langley, named for American astronomer S. P. Langley, equals 1 calorie of radiation energy per square centimeter per minute. This is equivalent to 220 Btu's per sq. ft. per hr.

LATENT HEAT Latent heat refers to the additional heat required to change the state of a substance from a solid to a liquid or a liquid to a gas without an appreciable change in its sensible temperature. The physical change of ice to water at 32°F requiring 144 Btu's per lb. are common examples of latent heat phenomena. This means large quantities of heat can be stored and extracted from a substance through a change of state. Glauber's salt has been used in a similar manner to increase the storage capacity of solar systems. Glauber's salt melts and freezes

within a 2°F spread at about 90°F with the addition or subtraction of approximately 108 Btu's per pound of salt. Therefore, a cubic foot of this salt (92 lbs.) can store about 80 times as many Btu's compared to a cubic foot of water (62.4 lbs.) at a 2°F temperature spread. The significance of latent heat storage compared to storing sensible heat as in water or rocks, is in reducing the storage volume required for a given thermal capacity.

LATITUDE Number of degrees north of equator (Northern Hemisphere). For example, about 40 degrees for New Jersey.

LIFE-CYCLE-COSTING (LCC) The LCC concept is where lifetime ownership costs, rather than just first costs, are the basis of comparison for the purchase of goods. To advance the use of solar systems, one of the factors which lenders will need to become cognizant of is the LCC concept as the payoff time for solar versus conventional heating systems is much longer. Also see PAYBACK.

LOAD The term "load" refers to the amount of Btu's required to perform the task of water and/or space heating. Solar systems are not normally designed to carry the entire thermal load of the intended application. For example, one source suggests solar hot water installations are best sized to carry 60 to 80% of the hot water load and from 40 to 60% of the annual heating load. The balance is provided by the conventional energy sources. Also see SIZING.

NOCTURNAL RADIATION This term refers to the exchange of longwave (infrared) radiation between the collector and the atmosphere. The occurrence takes place in daylight as well as night. However, the effect is far more noticeable at night when there is no incoming solar radiation. A very potent cooling effect is produced by nocturnal radiation which, if uncontrolled, causes a loss of stored heat from solar storage or possible collector freezeup.

OPEN LOOP SYSTEMS Systems in which the liquid solar heat transfer fluid is potable water. In areas which seldom go below freezing, hot water from storage is circulated through the collector as needed to prevent freeze-up. Where temperatures frequently go below freezing the collector is automatically drained down to prevent freeze-up. Also see CLOSED LOOP SYSTEM.

ORIENTATION Literally means collector position with relation to the points of the compass. While angle refers to

the tilt of the collector to the sun, orientation refers to the direction in which the collector points. A south orientation is theoretically ideal. Experience has shown that orientation slightly west of south will generally maximize daily and annual solar collection.

Two reasons have been advanced for this phenomena:

1) Incident radiation is sensitive to humidity which is generally higher in the early morning hours as opposed to the late afternoon hours. This means the collector efficiency is less in the morning and greater in the afternoon. Also see INCIDENT RADIATION.

2) Collector efficiency is also affected by the ambient air temperature in addition to incident radiation. Although solar insolation on a clear day is maximum at solar noon, maximum daytime ambient temperature will sometimes lag solar noon by 2½ to 3 hours. As a result, maximum collector efficiency occurs sometime after solar noon and before 3:00 p.m.

The foregoing may result in an optimum collector placement or orientation of ten to twenty degrees west of south in some locations. The freedom with which incident radiation can reach the collector surface (shading by buildings or trees), diurnal humidity and ambient temperature conditions will all have to be examined to achieve best orientation.

For most applications it is desirable that the collectors have an unobstructed view of the sun for at least six hours, ideally three hours on either side of solar noon. Also see SUN'S SWEEP.

PASSIVE SYSTEM A system requiring no energy other than solar energy in the collection, transport and storage of solar energy.

PAYBACK The payback or payoff of a solar system is viewed in terms of how many years are required to pay back the extra cost of the solar equipment with fuel savings.

The payback period depends upon the application and the cost of conventional energy. For example, space heating with natural gas (which is not a year 'round application) would be relatively long solar payoff. Supplementing a year 'round electric water heating system with solar energy would be quite favorable.

The lower operating cost is obviously the benefit of a solar system since the only fuel cost is that of the supplemental heat. Also see LIFE-CYCLE-COSTING.

PHASE-CHANGE MATERIAL A material used to store heat by melting. Heat is later released for use as the material solidifies. Also see GLAUBER'S SALT and LATENT HEAT.

PHOTOVOLTAIC CELLS (SOLAR CELLS) Semiconducting devices that convert sunlight directly into electric power. The conversion process is called the photovoltaic effect.

POTABLE WATER Water free from impurities present in amounts sufficient to cause disease or harmful effects to health.

PRESSURE DROP This term expresses the fact that power is consumed in moving liquids through the piping, collectors and other parts of the solar system. Or, expressed in another way, pressure drop is the amount of pressure lost between any two points in a system. Pressure drop is caused by the friction created between the inner walls of the conveyor and the moving liquid. Pressure drop is a major factor in the design of forced circulation systems. The friction or pressure drop in the system is directly related to the size of piping used and the design of other liquid carrying components. Also see HEAD PRESSURE.

PYRANOMETER An instrument for measuring sunlight intensity. It usually measures total (direct plus diffuse) isolation over a broad wavelength range.

PYRHELIOMETER An instrument that measures the intensity of the direct beam radiation (direct insolation) from the sun. The diffuse component is not measured.

R (R-VALUE OR RESISTANCE) The measure of a substance's ability to reduce transfer of heat or, in other words, its insulating value. Also see U.

RADIATION This is the process in which energy in the form of rays of light and heat are issued from a source. Also see RE-RADIATION and SOLAR RADIATION.

RE-RADIATION This is the phenomena of small amounts of solar energy being absorbed by the cover plates and sent back to the colder sky temperature. In addition, a portion of the heat collected on the absorber is also returned to the outside by infrared radiation. Also see INFRARED RADIATION.

ROCK STORAGE See STORAGE.

SIZING Sizing is the estimating of the demand to be placed upon the solar and supplemental heating systems by the heat requirements of the application.

The principal components involved in solar system sizing are the collectors, storage capacity and quantity of supplemental heat needed. Detailed calculations are obviously necessary to design an optimum system for each application.

SOLAR CELL See PHOTOVOLTAIC CELLS and PHOTOCHEMICAL.

SOLAR CONSTANT This is stated as a value of 429.2 Btu per square foot, on a plane perpendicular to the sun's rays, outside the earth's atmosphere. The solar constant undergoes considerable modification as it traverses the earth's atmosphere and arrives at the surface. See DIFFUSE and DIRECT.

SOLAR COOKER A device used for cooking with sun heat.

SOLAR DRYER A device used for drying crops or other substances.

SOLAR ENERGY The heat energy derived from the sun's rays is commonly referred to as solar energy.

Solar energy arrives at the earth's plane in two components . . . diffuse and direct. Also see DIFFUSE AND DIRECT.

SOLAR FLUX This is the (incident radiation/unit time) on a given collector surface and represents the available energy for heating purposes. This is a quantity, commonly measured in langleys or Btu per sq. ft. per hr., which must be established for rating the collector. Also see INCIDENT RADIATION and LANGLEY.

SOLAR FURNACE A device which is capable of producing temperatures as high as 7000°F through the use of concentrating collectors. Also see CONCENTRATING COLLECTOR.

SOLAR NOON Solar noon is when the sun is directly overhead and, on a clear day, solar insolation is maximum. The sun's rays pass direct through the atmosphere and on to the receiver with a minimum length of passage through the air.

SOLAR RADIATION Energy issuing from the sun in rays of light and heat.

SPECIFIC HEAT The amount of heat required to raise the temperature of one pound of a substance one degree compared to the amount of heat required to raise the temperature of the same mass of water one degree.

The following are examples of using specific heat values to compare the ability of air and water to transport and store heat energy:

1) The specific heat of air is 0.24 (depending upon temperature and condition). A cubic foot of air (.075 lbs.) raised 10°F can transport 0.18 Btu's. If the heated air is transported to a rock pile for storage of its heat content then the specific heat of rock must be known to estimate the quantity needed under design conditions.

The specific heat of rocks and similar solid materials is about 0.20. A cubic foot of solid rock weighs about 100 pounds and has a heat capacity of 200 Btu's when raised 10°F. Therefore, it would take about 83 pounds (about 1,100 cubic feet) of heated air to realize this amount of heat transfer.

2) The specific heat of water is 1. A cubic foot of water (62.4 lbs.) raised 10°F can transport or store 624 Btu's. A 1500 gallon storage tank contains about 12,500 pounds of water and could therefore store 625,000 Btu's at a 50° temperature rise.

Mixtures of water and anti-freeze result in lower specific heats for the fluid. For example, at 230°F, a 30% water 70% ehtylene glycol solution has a specific heat of .8.

STAGNATION Refers to a no flow condition in which collector and fluid temperatures rise due to exposure to sunlight.

THERMOSIPHON ACTION A gravity method of circulation which does not require a pump as the storage tank is located higher than the collector. Circulation is achieved by convection (liquid currents). The liquid expanding and rising as it is warmed . . . becoming more dense and falling as it is cooled.

The ASHRAE guide states that the day long efficiency of a well-constructed, properly-designed thermosiphon water heater ranges from 45 to 65% depending upon outdoor air temperature and wind velocity. Also see ACTIVE SYSTEM.

TRACKING Moving the solar collector to follow the sun and therefore increase collector efficiency.

TRANSPORT SYSTEM The transport system is the means through which the heat transfer fluid is moved to all parts of the solar system. Depending upon system design, the fluid may be propelled through ducts by fans or sent through the piping by

circulator or thermosiphon action. Also see ACTIVE SYSTEM, PASSIVE SYSTEM and THERMOSIPHON ACTION.

U (U-VALUE) Heat loss through any building surface in Btu's per square foot for each degree difference between inside and outside temperatures. Also See R.

WORKING FLUID Can be a liquid, a vapor or a gas.